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# The Whim Creek Group, a discussion

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**Abstract**

The Mallina Formation and the Constantine Sandstone should be placed in the Whim Creek Group, following the proposal of Fitton *et al.* (1975), and not in the underlying Gorge Creek Group as advocated by Hickman and Lipple (1975) and Hickman (1977). BIF in the Gorge Creek Group occurs above, but separated from, fuchsite-bearing metasediments; both lithologies are useful marker bands. Their distribution as fragments in the Constantine Sandstone gives additional data regarding the level of erosion that preceded the deposition of the Whim Creek Group. The Whim Creek Group consists of a predominantly clastic province and a predominantly volcanic province, separated, during sedimentation, by a hinge zone, which was the site of later emplacement of quench-textured rocks.

## Introduction

The Whim Creek Group has been described and defined by Fitton *et al.* (1975). The group occurs in the West Pilbara region of Western Australia, and rests unconformably on the Gorge Creek Group and the Teichmans Group, both of older Archaean age. These two underlying units are correlated respectively with the Soansville Sub-group (essentially) and the Warrawoona Group as defined in the eastern part of the Pilbara Block by Hickman and Lipple (1975). An account of relevant studies and of correlations with units of the eastern half of the Pilbara Block is given by Fitton *et al.* (1975).

The Whim Creek Group consists mainly of volcanic rocks in the Mons Cupri area and metasediments to the southeast, referred to respectively as a volcanic province and a clastic province by Horwitz and Smith (1978). The tectonic setting and relationship between these two provinces is illustrated in Fitton *et al.* (1975, Figs. 1, 2. I record here an error in Fig. 1; the Gorge Creek Group does not extend west of Loudens Fault, near Peawah Hill). Volcanics and sediments are considered to intertongue and to equate in time for all but the highest units in the clastic sequence. The type area for several of the volcanic members is defined at Mons Cupri, and the formations of the clastic province are equated to particular units of this type section (Fitton *et al.* 1975, p. 17).

The Whim Creek Group comprises the Warambie Basalt, Mons Cupri Volcanics, Constantine Sandstone and Mallina Formation; the formations are not well-developed everywhere, and in some places are absent. The Negri Volcanics have been excluded as they overlie the sequence, unconformably in places.

Hickman (1977) presents a map of part of the volcanic province which he names the Whim Creek Belt. Based on a relationship between porphyritic rocks and metasediments, 15 km southeast of Sherlock, as well as on an interpretation of structural data, he concludes (p. 56): "The mid-Archaean regional unconformity recognised by Fitton and others (1975) has not been substantiated by regional mapping . . . The Mallina Formation and Constantine Sandstone, placed by Fitton and others (1975) in the Whim Creek Group, belong to the Gorge Creek Group".

This paper presents new syntheses based on published data in support of Fitton *et al's*. thesis. For references to localities and to the distribution of rock units, the reader is referred to Fitton *et al.* (1975, Fig. 1), Hickman (1977, Fig. 28), and the 1:250 000 geological maps (Roebourne and Pyramid sheets) published by the Geological Survey of Western Australia.

## The Mons Cupri Volcanic Province

The Mons Cupri Volcanic Province is used in preference to the term "Whim Creek Volcanic Belt" so that one can include, within this province of volcanic rocks, those acid volcanics, tuffs and sediments which are preserved in the syncline between the Caines Well and the Balla Balla Granites (which are cut by Salty Creek and Balla Balla River), as well as the remnants, large rafts and roof pendants, in the gabbros and granophyres of the Millindinna Complex and in the possibly related granites, which occur between the George and Little Sherlock Rivers.

The basal unit of the Whim Creek Group in the Mons Cupri Volcanic Province is the Warambie Basalt which occurs wherever the basal contact is not intruded by units of the Millindinna

Complex. The basalt is more widespread than shown by Hickman (1977) between the Sherlock River and the road from Sherlock to Croydon. The Warambie Basalt is characteristically pitted by numerous small vesicles, recognisable even where the rock is sheared or altered. This, as well as their stratigraphic position, justifies including in the Warambie Basalt (as in Fitton *et al.*, Fig. 1) the basic rocks which occur between 2 and 5 km northeast of Mons Cupri. Pebbles of Warambie Basalt occur in clastics and in volcanic fragmentals in many exposures in the volcanic province of the Whim Creek Group.

The basal unconformity (Fitton *et al.* 1975, Hickman 1977) outcrops along the old road to Pyramid between Black Hill and Red Hill (between the George and Little Sherlock Rivers). There, the Warambie Basalt is nearly horizontal and rests on basic rocks in which regional folds plunge to the northwest. These are ascribed to the Teichmans Group. The unconformity is emphasised by the contrasting grades of metamorphism, estimated to be low in the overlying rocks which appear in hand specimen to be scarcely altered, whereas the underlying basic rocks appear to be amphibolite-grade rocks; the contained amphiboles are dark in colour and the rocks are strongly lineated. To the south, the Warambie Basalt is overlain by coarse clastic rocks and volcanic fragmentals (dolerite or gabbro intrudes the contact), and the dips steepen southwards. The Warambie Basalt here is therefore on the crest of the south-facing limb of an anticline.

Figure 1 is a geological cross-section at an azimuth of 210°, passing through the mine at Mons Cupri, approximately through Whim Creek Mine, and extending southwestward to 10 km from Mons Cupri. The deepest unit is the Mount Brown "Rhyolite Member". As suggested by Fitton *et al.* (1975, p. 16) and confirmed by later work (G. Sylvester, pers. comm. 1976), the unit is believed to be a chilled intrusive rock. Indeed, it contains many small xenoliths of country rock, particularly abundant close to the contacts. This unit forms a broad dome, intruding phyllites to the northeast and volcanic fragmentals to the south. Similar rocks occur elsewhere in the province.

The volcanic fragmentals ("Mons Cupri rhyolite fragmental") have been described by Miller & Gair (1975) and are now considered to be the oldest unit exposed in the section (Fig. 1). At the Mons Cupri mine the fragmentals are chloritized in places. This change masks the fragmental appearance but it becomes conspicuous again where the rocks are weathered. Mapping of the cleavage and the predominant orientation of the long axes of the fragments established that the fragmental unit is wedge-shaped, thinning rapidly towards the dome of the Mount Brown Member, but thinning more gradually southwards. Thus the volcanic fissure, or vent, responsible for the accumulation of the fragmental unit, was probably nearby to the north, and may have controlled the later emplacement of the intrusion of the Mount Brown Member. This general convergence of primary trends towards the north is reflected by the shape of the net-veined ore-body.

Sandstones, grits and conglomerates (Cistern Formation, Miller & Gair 1975) overlie the volcanic fragmentals. This unit correlated with the Constantine Sandstone by Fitton *et al.* (1975, p. 17) has caused much geological debate; it does intrude, or mix with, the underlying fragmentals, but on petrological examination it is essentially a tuffaceous grit. The bulk of the rock is massive, although graded bedding has been observed in drill core (K. O. Linn, pers. comm. 1972). At the top, it contains well defined layers, lenses and pockets of fine-grained material or boulder beds. Volcanic pebbles and fragments of fuchsite schist occur in places.

Phyllites overlie this unit and are equated (Fig. 1) with the phyllitic slate at Whim Creek and with the metasediments below the Negri Volcanics to the southwest.

Near Mons Cupri, a band of basic rock occurs close to the base of the Mallina Formation. It is too thin to depict in Figure 1. The rock is strongly altered and structureless, apart from some pronounced near-vertical jointing; its contacts with the phyllites are covered by rubble. The unit was named the Comstock Andesite by Miller & Gair (1975) but lacks volcanic criteria and is probably a fine-grained basic intrusive. Similar fine-grained basic rocks occur elsewhere

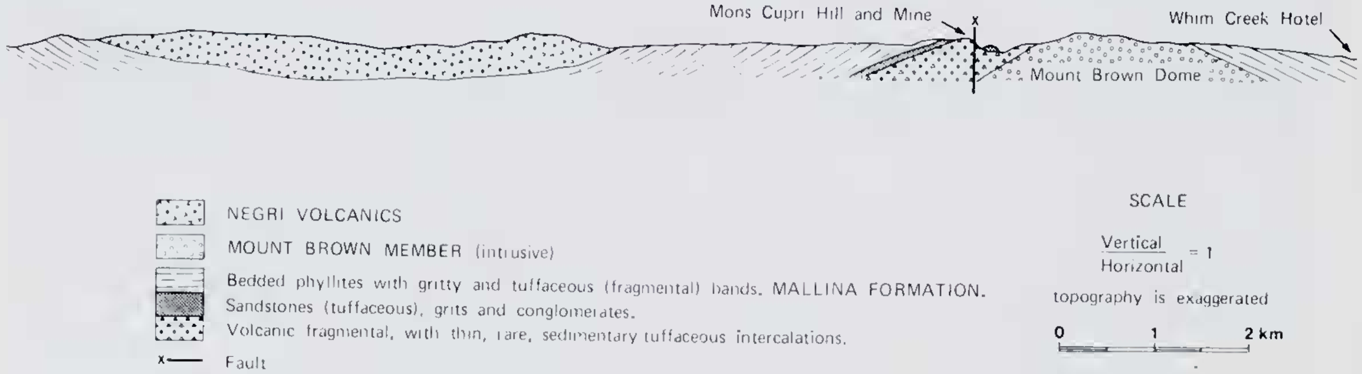


Figure 1.—Geological cross-section, striking 210°, through Mons Cupri Mine.

in the metasediments throughout the volcanic province. This does not, however, exclude the possibility of basic flows occurring with the sediments; indeed M. J. Fitton (pers. comm. 1977) has mapped possible lavas (a fine-grained basic rock) in the Mallina Formation near the Peawah River at Egina, in the clastic province.

Two areas of metasediments shown on Figure 1, flanking the Mount Brown Dome, are mapped by Hickman (1977, Fig. 28) as "slate (e.g. at Whim Creek)" and excluded from the Mallina Formation, whilst a third area, on the south limb of the syncline with Negri Volcanics, is included in the Mallina Formation. There is no evidence to indicate a discontinuity beneath this syncline. Hickman agrees (p. 55) that "the slate at Whim Creek lithologically resembles more pelitic parts of the Mallina Formation"; however, he has found that the sediments, beyond the southwest extension of Figure 1, dip under a porphyritic unit which he has included in the Mons Cupri Volcanics. These outcrops were accidentally omitted from the map in Fitton *et al.* (1975, Fig. 1). However, they do not contradict the conclusions of Fitton *et al.* regarding the extent, or unconformable nature of the Whim Creek Group. Such porphyries, some of which are flow-banded in places, are widespread throughout the volcanic province and were included by Fitton *et al.* as an integral part of the Mons Cupri Volcanics. Similar rocks have since been recorded in the Mallina Formation near its base, between Mt. Satirist and Millindinna by M. J. Fitton (pers. comm. 1977) and also about 10 km north of Egina by G. Doust (pers. comm. 1977), thus extending their distribution to the clastic province.

## Palaeogeographic evolution of the Archaean in the West Pilbara

Early mapping in the West Pilbara by Kriewaldt *et al.* (in Kriewaldt 1964) established a persistent sequence, applicable to the Archaean of the Pilbara Block west of Roebourne. The sequence, briefly described by Ryan and Kriewaldt (1963), was later abandoned (Ryan and Kriewaldt 1964, Ryan 1965) for the region between Mons Cupri and Mt. Satirist, following a misinterpretation of the relative ages of the later named Croydon Sandstone and the Gorge Creek Group (see Fitton *et al.* 1975, p. 5-6). The sequence from top to bottom (numbered as in Fig. 2) is, (4) Gorge Creek Group, BIF and sediments; (5) basic to intermediate volcanics, frequently pillowed; (6) a composite assemblage of mafic to ultra-mafic rocks with acid volcanics and sediments (Nickol River Formation of Williams 1968). Pillowed basalt underlies unit (6), where preserved by granitic intrusion. The granitoids intrude all units below the Gorge Creek Group.

Unit (6) is characterised by frequent occurrences of green fuchsite (a chromian muscovite) in the sedimentary bands. It is a complex stratigraphic unit (see Horwitz 1963). Correlations with the type section in the Teichmans region, where a similar sequence occurs, are shown in Figure 2; they were established with the help of M. J. Fitton. These chrome-bearing sediments, whose geochemistry still remains to be studied, could be genetically related to ultramafic volcanicity which, where developed, occurs in the same general part of the sequence.

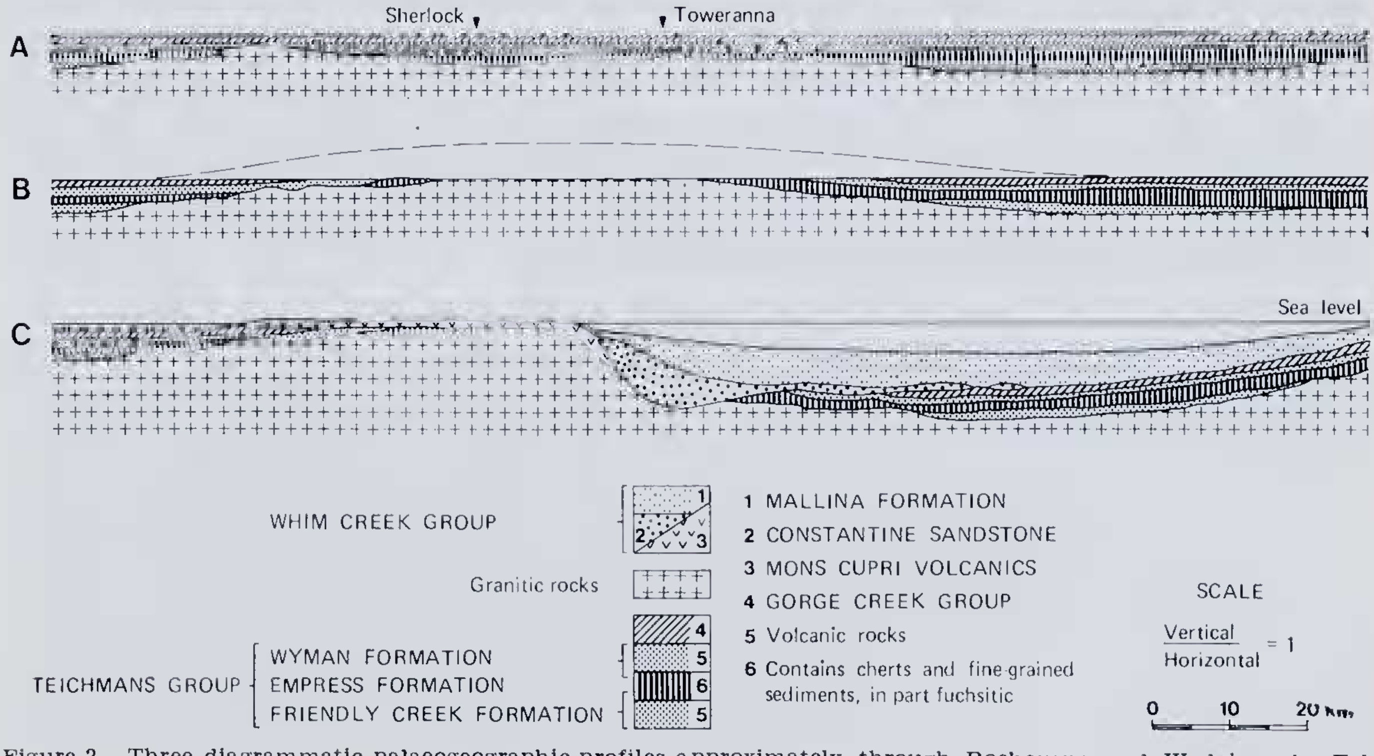


Figure 2.—Three diagrammatic palaeogeographic profiles approximately through Roebourne and Wodgina. A.—Following deposition of the Gorge Creek Group and intrusion by granitic rocks. B.—Prior to deposition of the Whim Creek Group. C.—After deposition of the Whim Creek Group.

The Gorge Creek Group BIFs, and the cherts and other sediments with the green fuchsite staining, thus provide two broad marker units which have been used to determine the level of erosion prior to deposition of the Whim Creek Group. These data have been used in association with the level of intrusion of the granites and the thicknesses and facies of the late Archaean rocks of the region in the compilation of the palaeogeographic profiles in Figure 2 which is based on the profiles in Fitton *et al.* (1975, Fig. 2).

Rare granitoid pebbles, as well as fuchsitic fragments, occur in the volcanic fragmentals at Mons Cupri, and fuchsitic fragments occur in the clastic metasediments correlated with the Constantine Sandstone at Mons Cupri. They are also present in the Constantine Sandstone of the Croydon Anticline, and the Mallina Anticline south of Loudens Fault. M. J. Fitton has recorded some, associated with fragments derived from the Gorge Creek Group, in the Constantine Sandstone north of Teichmans Goldmine. One can recognise a probable source for all of these clasts, including the fuchsitic fragments, which almost certainly derive from unit 6. In most other places, throughout the Teichmans and Mt. Satirist general area, the Constantine Sandstone contains chert and BIF pebbles derived from the Gorge Creek Group (Fig. 3). Such pebbles are usually well rounded. Very large slabs of chert and BIF occur at the base of the Constantine Sandstone north of Teichmans Goldmine; and in other areas the basal formation is a ferruginous breccia (M. J. Fitton, pers. comm. 1975). All this, when allied to an irregularity in detail of the surface of unconformity, indicates that the Gorge Creek Group was well lithified and eroded prior to the deposition of the Whim Creek Group. Where the Constantine Sandstone is very thin and reduced to a few metres of clastics, it has been omitted from Figure 2C.

The profiles in Figure 2 depict three stages in the evolution of the West Pilbara. Figure 2A is a profile after deposition of the Gorge Creek Group and following intrusion by granitic rocks. Nowhere in the West Pilbara are the fuchsitic sediments (6) in normal contact with the BIF (4); they are always separated by volcanic rocks.

Figure 2B indicates a broad arching of the sequence in the general area where granitic rocks have reached overall higher levels of intrusion. This might support the suggestion of M. J. Fitton (in Fitton *et al.* 1975) that the diapiric rise of granitoids is responsible for the structural deformation in the region. It is possible that this tectonism started before complete lithification of the Gorge Creek Group BIF as the latter show remarkable plastic deformation at both small and large scales. However,

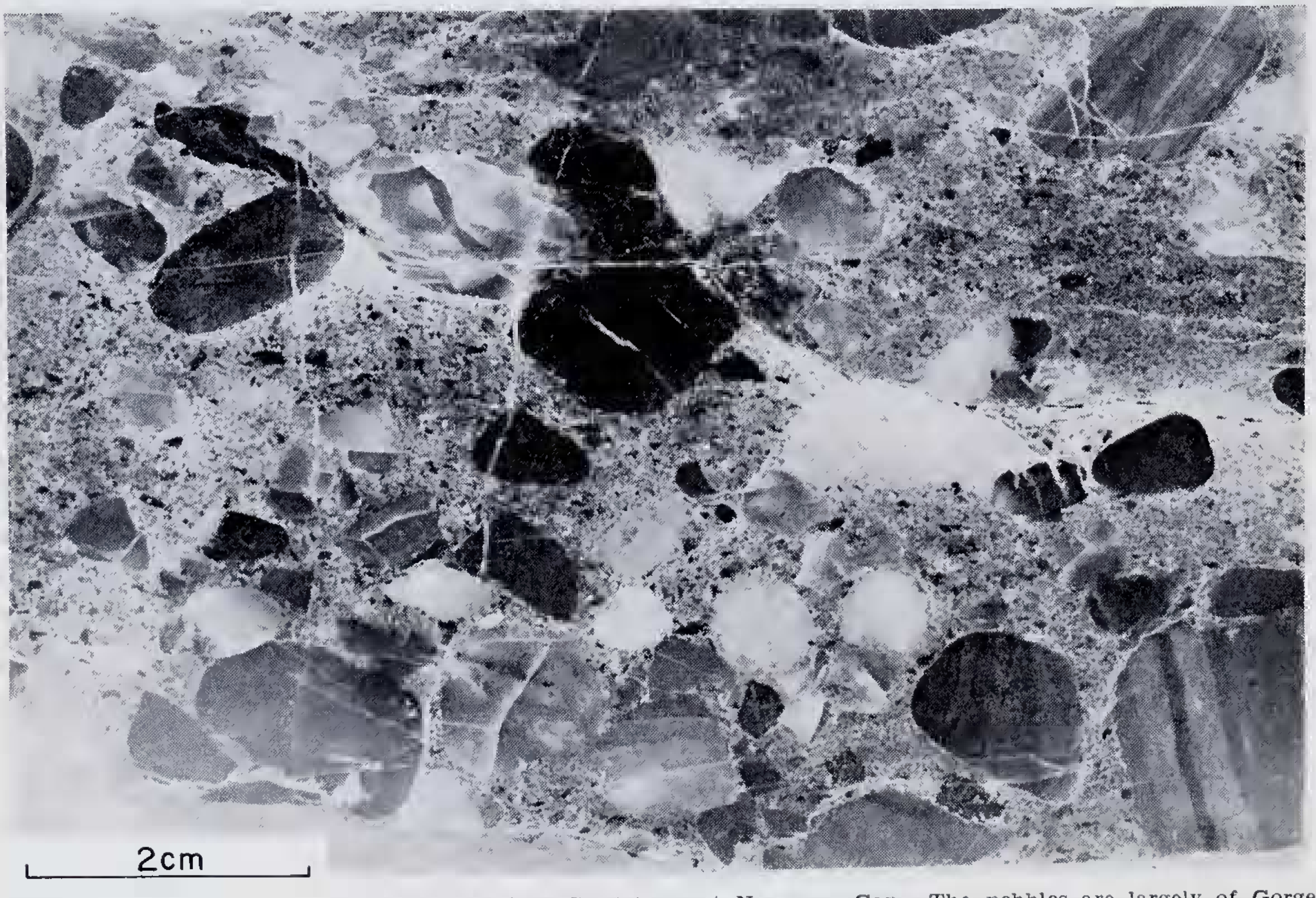


Figure 3.—Conglomerate from the Constantine Sandstone at Nunyerry Gap. The pebbles are largely of Gorge Creek Group BIF. Sample provided by M. J. Fitton.

diapirism, if it occurred, is considered to have been accompanied by clear intrusion with stoping and the injection of large granite sills and apophyses, as described by Horwitz (in Fitton *et al.* 1975, p. 19) for the Caines Well Granite. Indeed, the zone of mafic-ultramafic remnants, which was depicted in the granite from aeromagnetic maps, does outcrop in places as small and large remnants. The zone can be traced from the outcrops at Sherlock, southwestwards to an outcrop, adjoining and north of the new highway on the left bank of the Little Sherlock River (recorded in Fitton *et al.* 1975). Further westwards, the zone is displaced by the Copper Mine Fault, as the next outcrop is a small mound of granophyre of the Millindinna Complex (brecciated according to G. H. Riley, pers. comm.). The trace of the Copper Mine Fault, as depicted in Fitton *et al.* (1975) is confirmed by aeromagnetic data.

These remnants in the granites, as well as the country rocks in contact with the intrusive granites, are invariably metamorphosed to a high grade. It is to this contact effect that we attribute the metamorphic grade of the Teichmans Group amphibolites, below the Warambie Basalt. The contact effect also explains the previously unrecorded metamorphosed mafic-ultramafic rocks, preserved and sandwiched between the Millindinna Complex and the Croydon Sandstone at the Evelyn Copper Mine near Croydon (see also, Williams 1968, p. 7).

Where the dips are shallow the Mallina Formation phyllites have a pronounced cleavage resulting from flexure slip folding and subparallel to, but not to be confused with, the bedding. This occurs, for example, at Whim Creek, on both limbs of the Croydon Anticline a few kilometres away from the fold axis, near Egina, and northwest of Teichmans Goldmine. However, the steeper fracturing, or axial-plane cleavage is developed wherever the bedding is steeper, such as in the Mallina Formation near Mt. Negri, below the unconformity of the Negri Volcanics. Thus the steepness of the beds is not a criterion of age, as implied by Hickman (1977, p. 55).

Hickman (1977) has separated from the Negri Volcanics, his unit "Abu", the quench-textured basic rocks. West of the area covered by his map, close to and west of Warambie Homestead, the unit appears to intrude between the Warambie Basalt and other units of the Whim Creek Group. Its geographic distribution, largely flanking the volcanic province, (compare with Figure 2C) suggests that these mafic rocks are developed mainly at the hinge zone of thickness variations, which separates the volcanic province from the clastic province in the Whim Creek Group. As noted by Hickman (1977), this zone is marked by faults, the major one being Loudens Fault. These features could suggest that some deeper crustal control was possibly responsible for many aspects of the palaeogeography and mineralisation in the region.

Hickman (1977, Fig. 28), however, erred in separating these quench-textured rocks from others of the Negri Volcanics, such as those that overlie the Whim Creek Group in the syncline about 10 km south of Sherlock Homestead. Indeed, Hallberg (1973, p. 6) has noted similarities in textures and chemical affinities between his samples "Sherlock" and his samples "Mt. Negri Volcanics". The latter are from Hickman's unit "Abu" and the former from his "silicified and epidotised basalt".

Accepting that these two units are part of the same uninterrupted sequence, as originally mapped by Fitton *et al.* (1975), then the quench-textured basic rocks are unquestionably younger than the Whim Creek Group and cannot correlate with others of the Teichmans Group as suggested by Hickman (1977, p. 56). Indeed both Hallberg (1973) and Sun & Nesbitt (1978, p. 316) give chemical evidence showing that these quench-textured rocks of the Negri Volcanics are more differentiated than those common to the Archaean (for instance, Ruth Well, Hallberg 1973, Table 3).

## Conclusions

The Constantine Sandstone and the Mallina Formation are part of a sequence which is considered to be unconformable on, and thus excluded from, the Gorge Creek Group of BIF. The deposition of the Constantine Sandstone followed a period of erosion and folding; dissection must have proceeded at least as deep as unit (6). Thus the Whim Creek Group is a valid unit, which includes both volcanic and sedimentary rocks, and is distributed quite widely throughout the Archaean of the Pilbara Block. Its extent is indicated and discussed in Fitton *et al.* (1975, Fig. 3 and p. 23).

The relative ages of the Millindinna Complex, of some granitic rocks and of various rocks grouped with the Negri Volcanics, deserves more research. The age of some of these units might be a matter of semantics, to be solved by geochronological dating and an agreed definition of the boundary between the Archaean and the Proterozoic. Horwitz and Smith (1976, 1978) have shown that volcanicity was nearly continuous from late Archaean to early Proterozoic in parts of an early Proterozoic trough, superimposed on the area discussed in this paper. Indeed, there is still ample scope for further research in the region.

*Acknowledgements.*—The concepts outlined here are essentially those developed with M. J. Fitton and G. Sylvester, during research carried out prior to our joint paper in 1975. My thanks to all those acknowledged in Fitton *et al.* are here renewed and the opportunity is taken to repair the following omission: the comments by Anhaeusser (1971, p. 117), although pertinent to the unconformity of the Whim Creek Group, were not included in the historical section (Fitton *et al.* 1975, p. 2-9), because they were noted too late for publication. Since publication in 1975, my thoughts on the region have been clarified by discussion with and information supplied by M. J. Fitton and G. Sylvester and by discussions at the outcrops with R. Carey, G. Doust, A. Y. Glikson, R. C. Morris, A. S. Novikova, D. Philp, G. H. Riley and Sv. A. Sidorenko. The help, in recent discussions of J. A. Hallberg and E. S. T. O'Driscoll is also recorded. I thank both Mr. W. E. Ewers and Dr. E. H. Nickel for critically reading the manuscript and Mr. C. R. Steel for drafting the figures.

## References

Anhaeusser, C. R. (1971).—The Barberton Mountain Land, South Africa—A Guide to the Understanding of the Archaean Geology of Western Australia. In Glover, J. E. (edit.). Symposium on Archaean rocks held at Perth, 23-26 May 1970. *Geol. Soc. Australia Special Publication* 3: 103-119.

Fitton, M. J., Horwitz, R. C. and Sylvester, G. (1975).—Stratigraphy of the Early Precambrian in the West Pilbara, Western Australia. *Australia Commonwealth Sci. Industrial Research Organization, Minerals Res. Labs. Rept.* FP. 11, 31 p.

Hallberg, J. A. (1973).—Whole rock geochemical orientation trip to the Pilbara. *Australia Commonwealth Sci. Industrial Research Organization, Minerals Res. Labs. Rept.* FP. 3, 12 p.

Hickman, A. H. (1977).—Stratigraphic relations of rocks within the Whim Creek Belt. *Geol. Surv. West. Australia, Ann. Rept.* 1976: 53-56.

Hickman, A. H. and Lipple, S. L. (1975).—Sheet Marble Bar. *Geol Surv. West. Australia. Rec.* 1974/20.

Horwitz, R. C. (1963).—Facies changes in the Archaean of the Roebourne area, West Pilbara Goldfield. *Geol. Surv. West. Australia, Ann. Rept.* 1962: 37.

Horwitz, R. C. and Smith, R. E. (1976).—Bridging the Yilgarn and Pilbara Blocks, Western Australian Shield. Section 1A, No. 9, 25th International Geol. Congress, Sydney, August 1976. (Unpublished address).

Horwitz, R. C. and Smith, R. E. (1978).—Bridging the Yilgarn and Pilbara Blocks, Western Australia. *Precambrian Res.* 6: 293-322.

Kriewaldt, M. (1964).—Dampier and Barrow Island, Western Australia. *1:250 000 Geol. Series Explanatory Notes. Geol. Surv. West. Australia,* 13 p.

Miller, L. J. and Gair, H. S. (1975).—Mons Cupri copper-zinc-lead deposit. *In* Knight, C. C. (edit.). Economic Geology of Australia and Papua New Guinea—Metals. *Australasian Inst. Mining Metall. Mon.* 5: 195-202.

Ryan, G. R. (1965).—The geology of the Pilbara Block. *Australasian Inst. Mining Metall. Proceed.* 214: 61-94.

Ryan, G. R. and Kriewaldt, M. (1963).—Archaean stratigraphy in the Roebourne area, West Pilbara Goldfield. *Geol. Surv. West. Australia, Ann. Rept.* 1962: 38.

Ryan, G. R. and Kriewaldt, M. (1964).—Facies changes in the Archaean of the West Pilbara Goldfield. *Geol. Surv. West. Australia, Ann. Rept.* 1963: 28-30.

Sun, Shen-Su and Nesbitt, R. W. (1978).—Petrogenesis of Archaean ultrabasic and basic volcanics: Evidence from rare earth elements. *Contrib. Mineral. Petrol.* 65: 301-325.

Williams, I. R. (1968).—Yarraloola, Western Australia. *1:250 000 Geol. Series Explanatory notes. Australian Bur. Min. Res.* 30 p.